Uncertainty in Project Scheduling— Its Use in PERT/CPM Conventional Techniques

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ABSTRACT: In this article, PERT/CPM, as conventional tools for planning and controlling are discussed along with problems accompanied with their application. This article demonstrates a number of benefits, the most significant among them being that: PERT/CPM as conventional planning techniques needs to be scrutinized. Dealing with risk management in project management is now essential for minimizing losses and to enhance profitability. Yet, using floats, as stated by the traditional resource allocation method that is applied in most of current software, now needs to be investigated. PERT/CPM techniques are very common and widely adopted management tools, currently used in the processes of project planning and control. These techniques have been widely accepted in the construction industry. Despite the use of these techniques, experience shows that construction projects failed to achieve their defined objectives with respect to time and cost.

KEY WORDS: Costs, CPM, float, merge event bias, PERT, risk, and uncertainty

Project management is a discipline, which involves itself with undertaking of projects to achieve some form of benefits. Within this discipline, there is an extensive body of knowledge about tools and techniques available for project management. Part of this body of knowledge must concern itself with assessment of tools and techniques currently being implemented to meet the projects' goals and objectives.

Quite often, construction projects fail to achieve their objectives. The author's experience with many projects for different geographical locations indicates poor performance in terms of meeting time and cost targets. Uncertainties are inherently present in all construction projects. For many projects, additional information is needed to reduce risk and uncertainty to an acceptable level prior to commencement of work. With this uncertain and volatile environment, the need is vital for how uncertainties within a project can be analyzed and managed.

PERT/CPM is a vital technique used in scheduling construction projects. These techniques are very common and widely adopted management tools, currently used in the processes of project planning and control within the construction industry. The most recent software for planning and scheduling construction projects, is based mainly on PERT/CPM.

Problems Associated With PERT/CPM Techniques:

Planning and controlling projects is of paramount importance in the success of any construction project, because it constitutes a major part in the project's management life cycle. PERT/CPM techniques are very common and widely adopted management tools

Because of the nature of construction, the industry and its participants are widely associated with a high degree of risk and uncertainty. Although, a scheduling construction project by CPM does not provide a measure of uncertainty, most of the available software is based on CPM, it is deterministic tool. The duration of each activity is assumed to have one value. Yet the time required for completing an activity in a project depends on many factors, including the following.

- resources;
- methods;
- technology;
- site condition;
- weather; and
- regulations.

These are known in literature as risk drivers. The time required to complete an activity is not deterministic.

Experience from many projects indicates poor performance in terms of achieving time and cost targets despite the fact that PERT/CPM are being used. Many cost and time overruns appeared due to either unforeseen events, which may or may not have been possible for experienced professionals to anticipate, or foreseen events for which uncertainty was appropriately accommodated. It is suggested that a significant improvement to project performance may result from a greater attention to the whole of uncertainties and risks, correlated with the project.

Schedule control in construction is also of paramount importance in the success of any construction project. In spite continuous evolution in the project management field, the traditional approaches being used by practitioners show a lack of appropriate methodologies for controlling projects.

PERT Network

Program evaluation and review technique (PERT), developed by Malcolm and others in 1959, was the first attempt to quantify the uncertainty in activity durations and the project network [6, 7]. PERT as a technique, was initially developed to assist in planning of projects which attempts to account for inherent uncertainty of activity duration. PERT uses a three - time estimate duration which represents optimistic, pessimistic, and most likely estimates of activity duration. PERT computes the mean completion duration and its standard deviation along each continuous path through the schedule. In PERT method, forward pass and backward pass calculation are used to determine the event times of each activity and project duration. The critical path is calculated based on the mean duration of activities. Because average durations are used, the PERT critical path is different from the traditional critical path. PERT method attempts to estimate the uncertainty in the project schedule. It is a simplification of the risk analysis procedure. The assumptions that PERT is based on some critics, such as merge event bias, to rely on three-time estimates and variance consideration problem.

PERT technique assumes that the uncertainty associated with the overall duration is, approximately, a normal distribution. This derives from the central limit theorem, which states that the addition of an infinite series of distributions yields a normal distribution. The assumption is reasonable in practical networks, as long as a large enough number of activities on the critical path.

The PERT network illustrates a particularly simple situation in which there is obviously only one critical path. It assumes that the analysis is carried out on the critical path alone and this in itself can be problematic. In more complex networks, there are number of paths through the network; many of which may have the possibility of becoming critical depending on the duration of the individual activities on the paths. In order to investigate this problem, all paths, which have a prospect of becoming critical (because they have a low total float and high variance), shall be investigated. Figure 1, shows the results from a hypothetical network in which three routes R_1, R_2, and R_3 are treated as candidates for criticality. Each of the three routes gives, when analyzed using PERT, its own normal distribution for the project duration. When the probability density function (PDF) of the three routes is drawn, the resulting for project duration is as shown in figure 1. While R_1 is generally the most critical route, it can be seen that there is some likelihood that either R_2 or R_3 will become critical routes instead of R_1.

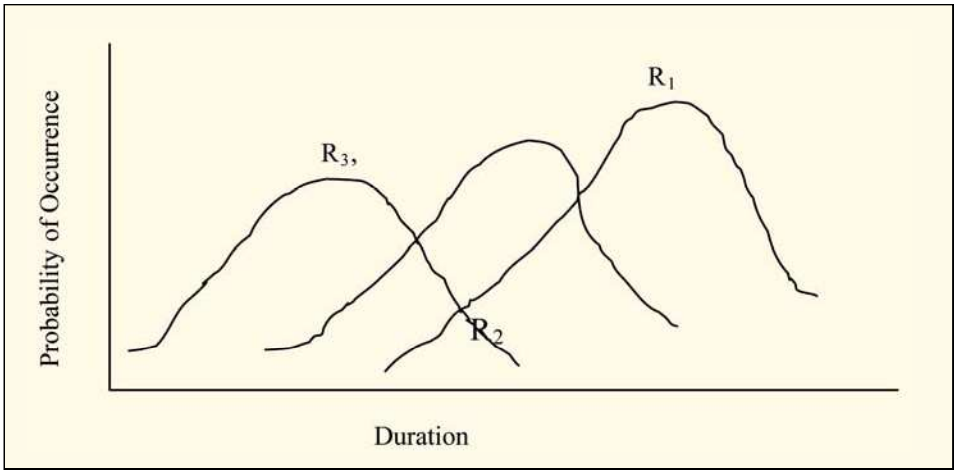

Figure 1— Project Duration Assuming a Variety of Critical Routes Through the Network [5]

M. Mawdesely obtained a number of problems associated with PERT; the most significant amongst them are [5]:

- The form of the distribution for the activity duration has very little basis in fact but is a convenient fiction;
- In small projects there may not be enough activities defining the project duration to make the assumption of a normal distribution for the project duration valid.
- The statistical analysis assumes that the activities are statistically independent. This is likely to be untrue. Activities following one another can be dependent, as can activities carried on at the same time, by the same resources or containing the same type of work. For example, activities performed consecutively by the same gang or subcontractor are likely to be related. Equally, similar outdoor activities going on at the same time on a project are likely to be affected by weather in a similar manner;
- The assumption that PERT is to be applied only to a single critical path means that the answers obtained always underestimate the duration of a project. The amount by which the method actually underestimates the duration of the project needs some investigation;
- The PERT technique requires a lot more information to be provided by the planner (in terms of the three estimates of duration for each activity). Although some schedulers view this as a drawback, others see it as a benefit because they are able to admit their inability to predict the duration of an activity more accurately;
- The method does not provide a single set of dates for control purposes and the use of the distributed results for control faces problems. However, as its name suggests, PERT can be used to produce updated estimates for project durations at various stages of the project. These are useful for control and decision making purposes; and
- The distributed nature of the timing of the activities means that the project demand for resource cannot be predicted and accurately controlled.

H. Adeli and A. Karim added number of shortcomings associated with PERT and CPM methods, these include [1]:

- Network methods do not guarantee the continuity of work in time, which may result in crews being idle;
- Multiple-crew strategies are difficult to implement in the network methods;
- The network diagram me is not suitable for monitoring the progress of a project; and
- Network methods do not provide an efficient structure for the representation of repetitive tasks. All tasks are represented similarly, and there is no consideration for the location of work in the scheduling.

Merge Event Bias

Merge event bias is one of the essential problems associated with PERT. Since PERT technique has been developed, one of its problems is the merge event ?bias. A merge event is defined as an event, which is connected with at least two paths, either the critical or the noncritical paths in a project network. The bias is caused by the influence of the subcritical paths in a project network on the total project time. The purpose of developing the merge event time estimation technique is to combine the uncertainties of both critical and noncritical path activities of a project network.

MacCrimmon and Ryavec illustrated the deviation of PERT calculated mean and standard deviation, from the actual mean and standard deviation [2, 14]. They demonstrated that, this deviation may be quite large when the paths are almost equal in length, and the difference decreases substantially as the path lengths become farther apart

MacCrimmon and Ryavec developed rules concerning merge event bias. They considered two of the more important factors affecting the magnitude of the merge event bias. First, one would intuitively expect the bias to increase as the number of parallel paths to the network and event increases. Second, one would also expect the bias to increase as the expected length of parallel paths become equal or almost equal in length. In fact, these two factors are approved by them and their result indicated that the deviation of the PERT calculated mean and standard deviation, from the actual mean and standard deviation, may be quite large when the paths are almost equal in length, but the difference decreases substantially as the path lengths becomes farther apart. To summarize, the results reached by MacCrimmon and Ryavec are as follows:

Rule I:

The magnitude of the bias correction at a given merge event increases as:

- The number of merging activity increases;
- The expected complete times of the merging activities get closer together;
- The variance of merging activities increase; and
- The correlation among the merging activity complete times approach zero.

Rule II:

If the difference between the expected complete times of the two merging activities being considered is greater than the larger of their respective standard deviations, then bias correction will be small; if the difference is greater than two standard deviations, the bias will be less than a small percentage and can be ignored (The difference referred to here is the activity free slack).

D. Gong and R. Hugsted developed a new analytical merge-event time estimation technique called the back-forward uncertainty estimation procedure (BFUE) [3]. The procedure includes the time uncertainties of noncritical path activities in the risk analysis of a project network. The BFUE procedure is consistent with PERT procedure and critical path method, and it is an improvement in the current merge-event time estimation technique.

The development of the BFUE procedure is based on the fact that a noncritical path can become a subcritical path through the use of the slack time along the path. A noncritical path could influence the total project time through both its time uncertainties and the use of its slack time.

D. Gong and J.E. Rowings introduced a new concept of time-disturbance analysis for a project network [4]. Time-disturbance analysis is a process of analyzing the change of the expected time of a given merge event or total project duration with the changes in the use of floats of noncritical activities. The disturbance of the scheduled activities is caused by the variance of activity durations in a network. A time disturbance can be caused by uncertainty of critical activities in a network, it can also be caused by the uncertainty of noncritical activities. In particular, when noncritical activities consume some or all of their floats, the possibility of time disturbance caused by noncritical activities can increase. With an increased use of float, the expected finish time of the noncritical merging activity gradually moves closer to the expected finish time of the critical merging activity concerned. Then the expected time of the given merge event increases correspondingly.

Gong and Rowings presented a procedure to optimize the use of floats in a project network by quantifying the safe float in noncritical activities that can be used for resource allocations and as an alternative for reducing project costs without causing negative impacts on the project duration [4]. In fact, Gong and Rowings' concept is based on one of the rules formulated by MacCrimmon and Ryavec [2, 3]; they interpreted this rule as:

> "at a given merge event with one critical activity and at least one noncritical activity, the calculated expected time of the merge event can be different when the expected finish times of the noncritical activities change. The expected time of the merge event increases when the expected finish times of the noncritical activities are closer to the expected finish time of the critical activities."

The time-disturbance analysis approach is applied to measure the impact of float use on the project's duration, and to calculate safe float for each noncritical activity. Accordingly, the late start and finish times of the activities will be calculated. Then, the risk of the project schedule overrun associated with float use and large uncertainties of the noncritical activities is evaluated, and the scenario concerning the optimum use of floats associated with the lowest project cost is identified. Accordingly, the start times of the noncritical activities are decided.

As known, floats are often used in project networks for resource allocations and as an alternative for reducing project costs without causing negative impacts on project duration. Limiting the use of floats to an identified safe range, as corroborated by Gong and Rowings, can reduce the risk of project schedule overruns but, it may not, however, be in the best interests of project cost control.

There is an uncertainty in every construction project. Uncertainty has become one of the major factors that influence a project's performance and ultimate success. Despite general awareness of the consequences of uncertainty on a project, little attention has been paid to its effect on construction management, particularly on the planning aspect.

Recent experiences show that projects failed to reach their defined objectives with respect to cost, time, and functional performance. Considering the amount of capital, recognition, and public interest invested in some projects, the consequences of these failures are often dramatic.

The conventional PERT/CPM techniques are very common and widely adopted management tool being used in project planning and control. Floats are often used in conventional PERT/CPM techniques for resource allocation, and as, an alternative for reducing costs without causing negative impacts on project duration. However, caution must be taken while using the floats of noncritical activities because there is a limit in using some floats of noncritical activities. If the floats used for noncritical activities are limited to the safe float, the risk of time overruns caused by noncritical activities can be eliminated or reduced. If the amounts of floats used are more than the permissible, this will lead to an increase in the completion time and, subsequently, leads to increased project cost. Adjusting or smoothing of resources by using float time of noncritical activities is controversial matter despite the prevalence of this approach. This argument will be consolidated if risk analysis is being applied.

There are also a good number of critics associated with the conventional PERT/CPM techniques. The most significant among them is the merge event bias. Many researchers had conducted this merge event bias problem, and as a result of that, some approaches were developed, in an attempt to overcome the limitation in PERT/CPM techniques. ◆

REFERENCES

1. Adeli, H. and A. Karim. *"Scheduling/ Cost Optimization and Neural Dynamics Models for Construction."* **Journal of Construction Engineering and Management**. Vol. 123, No. 4: (1997): 450-458.
2. Ahuja, H.N., S.P. Dossi, and S.M. AbouRizk. **Project Management, Techniques in Planning and Controlling Construction Projects**. John Wiley and Sons, Inc., 1994.
3. Gong, D. and R. Hugsted. *"Time-Uncertainty Analysis in Project Networks with a New Merge-Event Time-Estimation Technique."* **International Journal of Project Management**. Vol. 11, No. 3: (1993): 165-173.
4. Gong, D. and J.E. Rowings. *"Calculation of Safe Float Use in Risk-Analysis-Oriented Network Scheduling."* **International Journal of Project Management**. Vol. 13, No. 3: (1995): 187-194.
5. Mawdesely, M., W. Askew, and M. O'Reilly. **Planning and Controlling Construction Projects: the Best Laid Plans**. Addison Wesley Longman, 1997.
6. Perry, J. G. *"Risk Management-an Approach for Project Mangers."* **International Journal of Project Management**. Vol. 4, No. 4: (1986): 211-216.
7. Ranasinghi, M. and A.D. Russell. *"Analytical Approach for Economic Risk Quantification of Large Engineering Projects: Validation."* **Construction Management and Economics**. 10: (1992): 45-68.

RECOMMENDED READING

1. Akintola, A.S. and M.J. Macleod. *"Risk Analysis and Management in Construction."* **International Journal of Project Management**. Vol. 15, No 1: (1997): 31-38.
2. AL-Bahar, J.F. and K.C. Crandall. *"Systematic Risk Management Approach for Construction Projects."* **Journal of Construction Engineering and Management**. Vol. 116, No. 3: (1990): 533-546.
3. Ayyub, B.M. and A. Haldar. *"Project Scheduling Using Fuzzy Set Concept."* **Journal of Construction Engineering and Management**. Vol. 110, No. 2: (1984): 189-203.
4. Ben-Haim, Y. and A. Laufer. *"Robust Reliability of Projects with Activity-Duration Uncertainty."* **Journal of Construction Engineering and Management**. Vol. 124, No. 2: (1998): 125-131.
5. Bhuta, C. and S. Kharkhanis. *"Risk Simulation and Risk Management for Building Project."* **Construction Process Re-engineering**. (1997): 81-89.
6. Chapman, C.B. "A *Risk Engineering Approach to Project Risk Management."* **International Journal of Project Management**. Vol. 8, No. 1, (1990):5-16.
7. Cohenca, D., A. Laufer, and W.B. Ledbetter. *"Factors Affecting Construction Planning Efforts."* **Journal of Construction Engineering and Management**. Vol. 124, No. 2: (1989): 125-131.
8. Cooper, D. F. and C.B. Chapman. **Risk Analysis for Large Project**. John Willey and Sons Ltd., 1987.
9. Cox, D. C. and P. Baybutt. *"Methods for Uncertainty Analysis: a Comparative Survey."* **Risk Analysis**. Vol. 1, No. 4: (1981): 251-258.
10. DeFalco, M. and R. Macchiaroli. *"Timing of Control Activities in Project Planning."* **International Journal of Project Management**. Vol. 16, No. 1: (1998): 51-58.
11. Gong, D. *"Optimization of Float Use in Risk Analysis-Based Network Scheduling."* **International Journal of Project Management**. Vol. 15, No. 3: (1997): 187-192.
12. Jaafari, A. *"Time and Priority Allocation Scheduling Technique for Projects."* **International Journal of Project Management**. Vol. 14, No. 5: (1996): 289-299.
13. Kerzner, H. **Project Management - A System Approach to Planning, Scheduling and Controlling**. John Wiley & Sons, Inc., 2003.
14. Li, S. *"Construction Schedule."* **Journal of Construction Engineering and Management**. Vol. 122, No. 1: (1996): 7-13.
15. Moder, J.J., C.R. Philips, and E.W. Davis. **Project Management with CPM, PERT and Precedence Diagramming**. Van Nostrand Reinhold Company, 1983.
16. Mummolo, G. *"PERT-Path Network Technique: A New Approach to Project Planning,"* **International Journal of Project Management**. Vol. 12, No.2: (1994): 89-99.
17. Naoum, S.G. *"Critical Analysis of Time and Cost of Management Traditional Contracts."* **Journal of Construction Engineering and Management**. Vol. 120, No. 4: (1994): 687-705.
18. Omar, A. MSc Dissertation, *"Time-Uncertainty Analysis by Using Simulation in Project Scheduling Networks,"* UPM, Malaysia (Unpublished) 2000.
19. Ranasinghi, M. *"Quantification and Management of Uncertainty in Activity Duration Networks."* **Construction Management and Economics**. 12: (1994): 15-29.
20. Ranasinghi, M. and A.D. Russell. *"Elicitation of Subjective Probabilities for Economic Risk Analysis: an Investigation."* **Construction Management and Economics**. 11: (1993): 326-340.
21. Rowe, W.D. **"Understanding Uncertainty." Risk Analysis**. Vol. 14, No. 5: (1994): 743-750.
22. Russell, A.D. and M. Ranasinghi. " *Analytical Approach for Economic Risk Quantification of Large Engineering Projects."* **Construction Management and Economics**. 10: (1997): 277-301.
23. Simister, S.J. *"Usage and Benefits of Project Risk Analysis and Management."* **International Journal of Project Management**. Vol. 12, No. 1, (1994): 5-8.
24. Ward, S.C. and C.B. Chapman. *"Risk-Management Perspective on the Project Life Cycle."* **International Journal of Project Management**. Vol. 13, No. 3, (1995): 145-149.
25. Ward, S.C., C.B. Chapman, and B. Curtis, B. *"On the Allocation of Risk in Construction Projects."* **International**

Journal of Project Management. Vol. 9, No. 3 (1991): 140-146.

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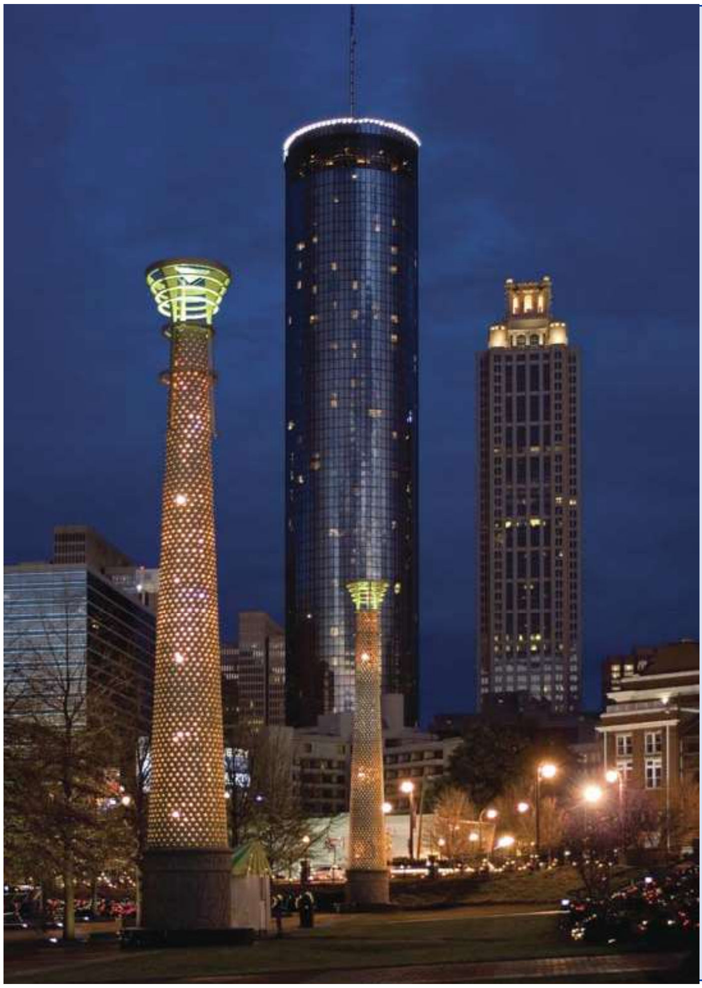

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